Project Details

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Selection Year: 2020
Program Element: Focused Science Topic

Topic: Modeling and Validation of Ionospheric Irregularities and Scintillations

Project Title:
Simulating radio wave propagation and scintillations through the turbulent ionosphere

PI Name: Meers Oppenheim
PI Email: atn@g.ucla.edu
Affiliation: Boston University
Project Member(s):
- Dimant, Yakov S;Co-I;Boston University
- Longley, William James;Co-I/Science PI;Boston University
- Young, Matthew;Co-I/Institutional PI;University of New Hampshire, Durham

Summary:
Science Goals: Disturbances in the Earth s ionosphere frequently disrupt radio waves transmitted through it in a process called scintillation. These disruptions often cause a loss or degradation of GPS and Earth-space communication, a major space-weather problem. The goal of this project is to model the propagation of radio waves through simulated ionospheric irregularities with the objective of learning how to mitigate these effects. Specifically, this research will perform massively parallel simulations of plasma density irregularities generated by the high latitude gradient-drift instability (GDI). The output of these simulations will then be used in another set of high-resolution simulations to obtain quantitative information about how radio waves propagate and scintillate through a disturbed ionosphere. These modeled impacts will then be compared to observations, both previously archived and those generated by other members of the Focused Science Team. In order to reduce the effects of scintillation we will analyze the high latitude irregularity spectra driven by the GDI, and examine the relationship between scintillation at various frequencies.
Methodology: The main product of this research is to develop and validate a massively parallel Finite Difference Time Domain (FDTD) simulation for propagating radio waves through a turbulent plasma. The FDTD method simulates realistic wave forms and will enable a study of the scintillation effects on different transmitted frequencies with realistic bandwidths. The inputs for the FDTD simulation will be density perturbations from kinetic and hybrid GDI simulations using the Electrostatic Parallel Particle-in-Cell (EPPIC) code. EPPIC is a robust, mature simulator that has been used extensively to study the nonlinear evolution of electrostatic instabilities, including the GDI and Farley-Buneman instabilities. Recently a 2D hybrid version of EPPIC simulated the secondary Farley-Buneman instability occurring within a larger gradient drift instability. This research will develop a 3D solver for the hybrid version of EPPIC, allowing it to simulate the evolution of the plasma along the vertical magnetic field direction. The coupled FDTD and EPPIC code will provide a unique and realistic simulation of radio and microwave propagation and scintillation through the high latitude GDI in both the E and F regions. The FDTD simulation will calculate scintillation indices, allowing for comparisons to ground based data and other model outputs.
Relevance to NASA Objectives: The FDTD simulations will enable quantitative modeling of radio wave propagation at a range of frequencies, directly addressing the objective to identify the relationship between scintillation at various frequencies. The FDTD code will also be designed to couple with other plasma simulation models to investigate scintillation from other instabilities. The hybrid simulations in this research will improve the community s understanding of the gradient-drift instability at the smallest relevant scales, where current measurements of the irregularity spectra are difficult to make. The hybrid simulations combined with a theoretical analysis will help to determine the growth rates, spectral characteristics, and nonlinear evolution of the GDI and its role in scintillation, as well as to help identify the instability mechanisms responsible for polar F-region irregularities. The gradient-drift instability is inherently a space weather effect, so studying the scintillation it causes directly advances the NASA Living with a Star objective to obtain scientific knowledge relevant to mitigation or accommodation of undesirable effects of space weather effects on humans and human technology on the ground and in space.

Publication References:

no references